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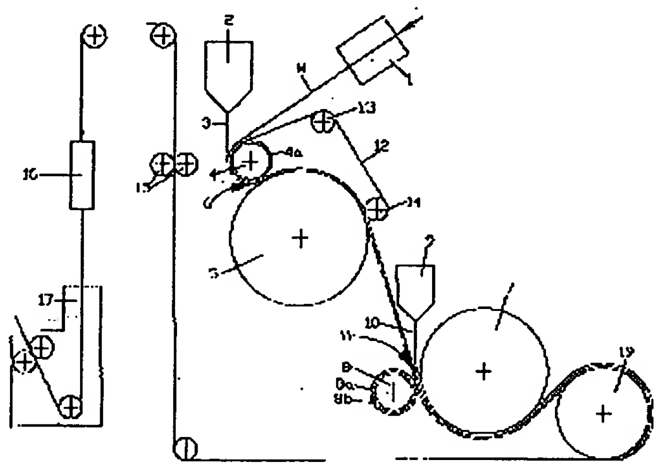
(54) **METHODE ET APPAREIL PERMETTANT DE PLASTIFIER DES BANDES DE METAL PAR EXTRUSION DIRECTE**

(54) **METHOD AND DEVICE FOR PLASTIC LAMINATION OF METAL STRIP BY MEANS OF DIRECT EXTRUSION**



(57) Méthode permettant de recouvrir de plastique une bande de métal par extrusion directe. Selon cette méthode, la bande de métal est déplacée en direction longitudinale puis chauffée. Au moyen d'une filière d'extrusion pour feuilles, une pellicule d'un matériau plastique fondu thermoplastique est déposée directement sur un côté de la bande de métal en déplacement et est pressée sur celle-ci tout en étant guidée dans un espace entre deux rouleaux, c'est dans cet espace que le rouleau adjacent à la pellicule de plastique (rouleau de laminage) est maintenu à une température inférieure au point de fusion du matériau plastique. Si nécessaire, l'autre côté

(57) In this method for plastic lamination of a metal strip by means of direct extrusion, in which the metal strip is moved in its longitudinal direction, and is heated, by means of a sheet die, a film of molten, thermoplastic plastic material is deposited directly onto one side of the moving metal strip, this plastic film is pressed onto the metal strip, while being led through a gap between two rollers, by which the roller adjacent to the plastic film (laminating roller) is maintained below the melting temperature of the plastic material; if necessary the other side of the metal strip may be coated with a plastic film in similar fashion. While laminating a steel strip, the

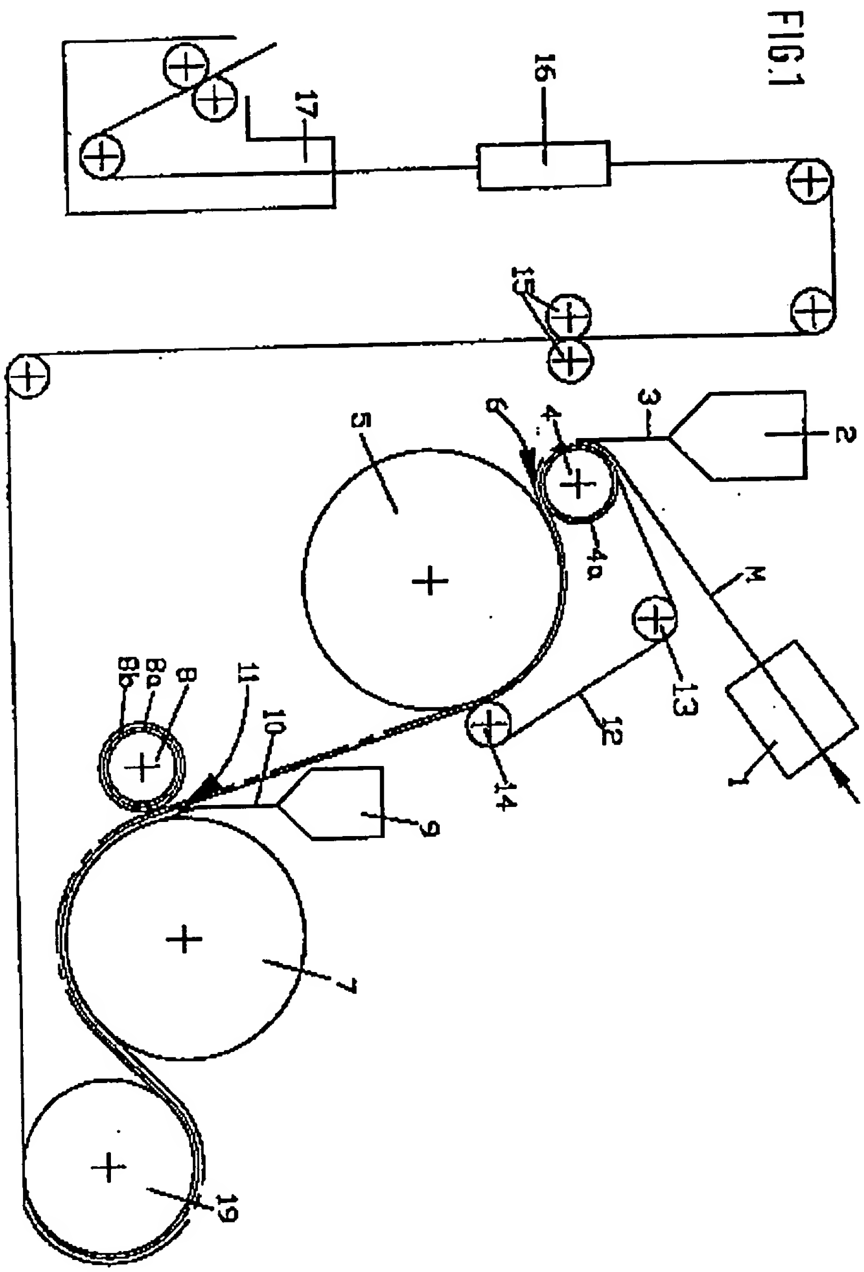


FIG.1

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FIG.2

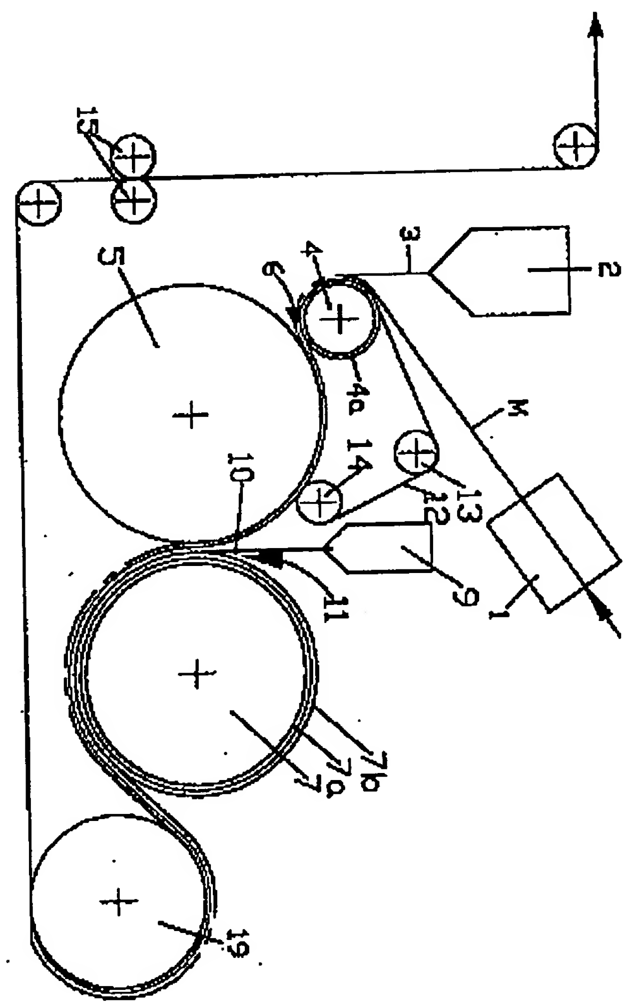

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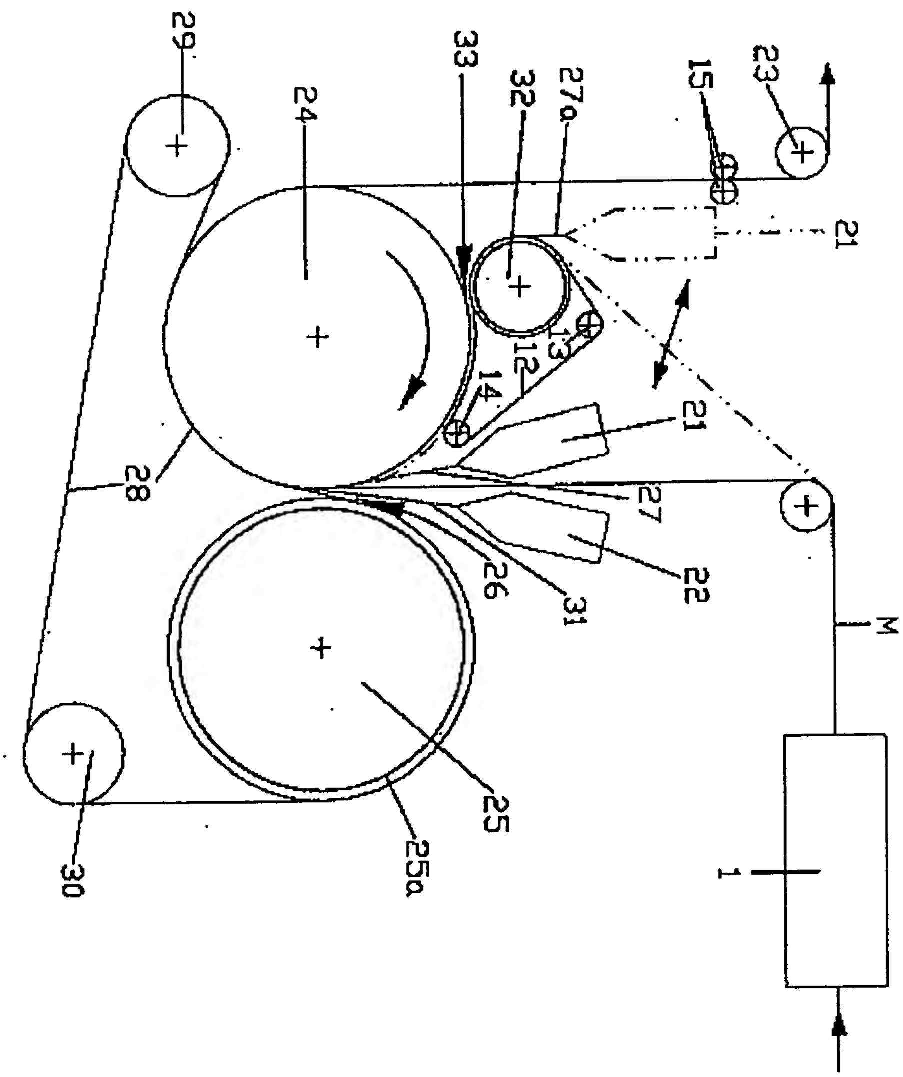
FIG.3



Method and Device for Plastic Lamination of Metal Strip by means of Direct Extrusion.

The invention relates to a method for plastic lamination of a metal strip by means of direct extrusion, in which the metal strip is moved in its longitudinal direction, and is heated; by means of a sheet die, a film of molten, thermoplastic plastic material is deposited directly onto one side of the moving strip, this plastic film is pressed onto the metal strip, while being led through a gap between two rollers, by which the roller adjacent to the plastic film (laminator roller) is maintained below the melting temperature of the plastic material; if necessary the other side of the metal strip may be coated with a plastic film in similar fashion and, in a subsequent treatment, the laminated metal strip is heated to a temperature in the region of the melting point and finally cooled rapidly to a temperature below 40_C.

Furthermore, the invention also relates to a device for plastic lamination of a metal strip by means of direct extrusion.

In a known method of the type mentioned above (US 5 407 702, Fig.3), an aluminium strip is heated, before laminating with PET (polyethyleneterephthalate), to a temperature in the range of 204-260_C, preferably 215-246_C and led through the gap between two rollers. Before entering the gap, the liquid plastic film is deposited on

one side of the aluminium strip. The roller pressing on the plastic film is a chrome steel roller and is kept at a temperature of 150-200_C. The roller adjacent to the unlaminated side of the aluminium strip is a rubber encased roller and has a surface temperature of 205_C, in order to keep the aluminium strip up to temperature. The layer thickness of the deposited plastic film should be approx. 8-20 μm, preferably 10μm. After the aluminium strip, which was laminated on one side, has left the first pair of rollers, lamination on the other side is achieved by means of a second sheet die and a second identical pair of rollers. In this procedure, the adhesion of both plastic films to the aluminium strip is slight at first, but just large enough, that the plastic films do not separate from the aluminium strip in the course of further processing, which is described as "green peel strength". After the aluminium strip has been laminated in this way on the second side too, it is led through an induction heater, where it is heated to approx. 215_C. As a result of this heating, the bond between the plastic films and the aluminium strip should be completed. Next, the bonding system is cooled using spray jets to a temperature firstly, which allows the half-cooled, laminated aluminium strip to be fed into a water bath via a deflection roller, where it is cooled down to a temperature below 40_C. In this known method, line contact or contact between the roller adjacent to the liquid plastic film and the plastic material is only achieved via a relatively small contact surface.

The cooled roller is therefore only in contact with the plastic film for a very short time. Separating the roller surface from the plastic film may only result, however, when at least the surface layer of the plastic film is solid since the plastic film adheres otherwise to the roller and contaminates the latter. So that the plastic material in the gap region can cool sufficiently, a very low speed must be used for the strip, making economic production impossible. Laminating a steel strip in place of an aluminium strip and using greater layer thicknesses of plastic material with for example 200μm, this method could definitely not be used since heat could not be dissipated quickly enough through the adjacent roller with line contact only because of the higher heat capacity and lower heat conductivity of the steel strip and because of the greater layer thickness of the plastic film. In addition, the adhesion between the plastic film and a steel strip would not be adequate after leaving the rollers to prevent a separation of the same from the steel strip using greater film thicknesses, in which there is a high occurrence of shrinkage while cooling.

Therefore, the object underlying the invention is to indicate a method of the type mentioned at the beginning which can be accomplished in economic conditions, i.e. with sufficiently high strip speeds and which results, at the same time, in excellent adhesion between the steel strip and the plastic film, which remains in place even during deep-drawing, but particularly also during

sterilisation. In addition, the object underlying the invention is to create a device for plastic lamination of a metal strip by means of direct extrusion, which makes it possible to laminate metal strips at high strip speeds and with excellent adhesion between the metal strip and the plastic film.

The method according to the invention is characterised in that, during lamination of a steel strip, the latter is heated to such a temperature that the temperature lies above the melting temperature of the respective plastic material in the depositing region of the liquid plastic film, in that, between the roller pressing on the plastic film (laminator roller) or a continuous belt pressing on the plastic film (laminator belt), there is surface contact and that this surface contact is maintained by synchronous conveyance of the surfaces of the plastic film and the laminator roller or laminator belt, which are in contact, via a contact time or contact length which suffices for cooling at least the surface layer of the plastic film at a belt speed of at least 50m/min and with a cooling rate of at most 400 W/m^2_C to a temperature lying at least around 30_C below the melting point of the respective plastic before contact is lost between the plastic film and the laminator roller or laminator belt.

Advantageous processing measures are given in the Sub-claims 2-13.

Devices according to the invention for plastic lamination

of a metal strip by means of direct extrusion are characterised in the Claims 14-24.

During lamination, the liquid plastic film is extruded directly onto the steel strip. Then, the plastic film is pressed onto the steel strip by the laminator roller or laminator belt. The laminator roller or laminator belt then takes over the job of cooling the plastic film in order to convey it from the liquid phase into the solid phase. The laminator roller or laminator belt, which for the sake of simplicity are known only as laminator in the following, can serve, because of their surface structure, for shaping the surface of the plastic film as well. While the plastic film is cooling, the latter experiences transverse shrinkage which, if certain measures were not taken, would lead to the plastic film peeling off the steel strip. This is particularly the case when the plastic film has a thickness greater than up to 200µm. It must be established, that the adhesion capacity in the bond between the steel strip and the plastic film increases more quickly while cooling, than the shrinkage capacity in the plastic film. For this purpose, certain measures are mandatory, namely heating the steel strip so that, in the depositing area of the liquid plastic film, temperatures are kept above the melting point of the plastic (e.g. for PP [polypropylene] : 190°C, for PET [polyethyleneterephthalate] : 290°C and for PE [polyethylene] : 130°C, also pressing the liquid plastic film onto the steel strip with sufficient contact time or

contact length and sufficient pressure and also with a cooling rate which is effected by the laminator and which is not more than 400 W/m^2_C.

Separation of the laminator from the plastic film can only result when at least the surface layer of the plastic film is converted by cooling into a solid condition. The adhesion of the plastic film to the steel strip must be greater than that of the adhesion to the laminator. Otherwise, particles of plastic material adhere to the laminator, which leads not only to contamination of the laminator but also to a momentary separation of the plastic film from the steel strip and to an irreversible loss of adhesion as well as eventual transverse shrinkage.

In order to achieve adequate cooling of the plastic film at belt speeds of over 50m/min and preferably more, which permit rational production, the invention envisages that while the steel strip is moving, the plastic film is held in position on the laminator for an adequate period of contact by surface contact between the plastic film and the laminator for the time required for cooling and that it is pressed onto the steel strip at the same time. A longer contact time and greater contact length (in the direction of movement of the belt) is particularly required for converting at least the surface layer of the plastic film, which is adjacent to the laminator, into a solid state by cooling when there are greater film thicknesses of for example 200µm and an essentially

smaller heat conductivity relative to aluminium, and also a higher heat capacity in the steel strip.

When the plastic film is being cooled by the laminator, the cooling rate should not be higher than 400 W/m^2_C since otherwise, when using the size of film thicknesses mentioned, and because of too speedy transverse shrinkage of the plastic film, the latter separates in part from the steel strip and a loss of adhesion occurs.

So that the liquid plastic film is pressed onto the steel strip to a sufficient degree by the laminator, this should be done with a force of at least 60 N/mm of steel strip width.

So that the adhesion between the plastic film and the steel strip is improved, an adequate reaction time must exist between the liquid plastic material and the surface of the heated steel strip. In order to achieve this, the temperature of the steel strip in the depositing area of the plastic film should be at least around 10°C preferably however around 20°C or more above the melting point of the respective plastic material.

A sufficiently long contact time between the plastic film and the laminator can be achieved by leading the steel strip with the plastic film which is adjacent to a laminator roller under tension over a part of the circumference of the laminator roller.

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A continuous laminator belt is likewise led with tension together with the laminated steel strip round part of the circumference of the roller, the plastic film, which is cooling down and adjacent to the laminator belt, being held on the laminator belt till at least its surface layer is converted into a solid condition. Cooling results in this case by means of the laminator belt, which can usefully consist of steel, on the one hand, and by means of the partly encircled roller on the other.

This method is particularly appropriate for laminating steel strips on both sides, the encircled roller being designed as a cooling laminator roller which presses the first plastic film to one side of the steel strip while the second plastic film is pressed by the laminator belt onto the other side of the steel strip and then cooled.

For the abovementioned reasons, during cooling of the plastic film by means of laminators, the cooling rate (heat transmission coefficient) should not be greater than 400 W/m^2_C, to ensure the desired level of adhesion.

This cooling rate is however not sufficient for keeping the growth of crystallites or spherulites small, particularly using PP. Exceeding a critical spherulite diameter leads with PP to a clouding of the plastic film and to so-called white breakage during reshaping of the laminated steel strip into packaging material. This is also true to a lesser extent for PET, the spherulite

growth rate of which is however considerably smaller than that of PP. However, even with PBT a plastic film in an amorphous form with as few crystallites as possible is aspired to, in order to guarantee a high degree of ductility. In order to reduce the amount of spherulites or to make an amorphous structure, the completed laminated steel strip is heated after the laminator to a temperature above the melting point of the respective plastic material, e.g. with PP above 200°C, with PET above 300°C. Subsequently, rapid cooling must occur by plunging in water at room temperature, so that, when remaining below the crystallisation temperature which lies immediately below the deformation point, renewed growth in crystals does not occur (spherulite growth). For homo-PP the cooling rate should be at least 200°C/s, and for a random-PP at least 100°C/s. In order to achieve this, heat transmission coefficients for the laminated steel strip must be produced in water of at least 3000 W/m^2 °C or at least 1800 W/m^2 °C. This implies the necessity for high relative speeds between the laminated metal strip and the water (30-100 m/min), to ensure turbulent transportation of material or heat.

When both sides are to be laminated with plastic materials which have varying melting points, care must be taken. that the plastic material which is deposited first, has the higher melting point, since, at the beginning, the steel strip has the highest temperature. When the plastic film which is deposited first, e.g. PET, is pressed onto

the steel strip by a first laminator and is thereby cooled, the steel strip is then also cooled simultaneously to a lower temperature. As long as the temperature of the steel strip remains above the melting point of the second plastic film however, e.g. PP, the PP plastic film is extruded on the now cooler steel strip. The strip temperature difference for the two laminations of PET and PP is about 100 °C.

The deposition of the liquid plastic material on the steel strip is achieved by means of a sheet die, at a width for this purpose which is greater than the width of the steel strip. The thickness of the emergent plastic film is determined by the adjustment of the gap in the die. Since the steel strip possesses a higher strip speed relative to the die exit speed, the plastic film is pulled longitudinally and becomes thinner. Thereby, a reduction in breadth also takes place, which leads to an even distribution in thickness of the film over its breadth. The edge areas are thicker than the central region. For this reason, a plastic film is produced which has a greater width than that of the steel strip, with the result that the thicker edge areas on the steel strip exceed approx. 20-30mm. In order to protect a pressing-on roller which is located opposite the laminator roller from contamination from projecting plastic film, continuous Teflon strips are led on both longitudinal edges of the steel strip in the depositing area and adjacent to said strip synchronously with the steel strip, until the

sections of plastic film projecting sideways over the steel strip are cooled adequately to below melting point. After the plastic film has set, the protruding plastic film on the steel strip can be trimmed. If the plastic films on both sides of the steel strip are different, they are suctioned off separately, so that they can be sent for recycling.

Devices according to the invention for plastic laminating on both sides of a metal strip by means of direct extrusion are described in greater detail in the following with the aid of embodiments which are represented schematically in Fig. 1-3 of the drawing.

In all three embodiments, the heating device, the device for subsequent heating of the laminated steel strip and the cooling device are all the same, for which reason they are described in greater detail only in the embodiment example represented in Fig. 1. The metal strip is preferably a steel strip, which can also be surface treated with tin plating, chrome plating or conversion laminating. With the devices according to the invention however, other metal strips, for example aluminium strips can also be laminated. The metal strip can have a thickness of 0.05 -0.5mm. Thermoplastic plastic materials, such as PBT, homo-PP, block PP, random PP and PE can be used for laminating. The film thicknesses can thereby be 5 - 200μm on one side and 3 - 10μm on the other side. Both sides of the metal strip can be laminated with

the same or different plastic materials depending on application requirements. The operation can be carried out with belt speeds of 50-400 m/min.

According to Figure 1 the metal strip M is directed firstly through a heating device 1. Next to this is a first laminating station. The latter has a first sheet die for directly depositing the molten thermoplastic plastic material in the form of a first liquid plastic film 3 onto the first side of the heated metal strip M. The plastic film can consist of two layers in a known fashion. The layer orientated towards the metal strip can ensure, especially with a steel strip, the adhesion of the plastic film to the metal strip. The outer layer should be selected for the integrity of the packaging, with respect to the contents, which is produced from the laminated metal strip or for its resistance with respect to outer stresses. In order to produce a plastic film with a two-layer design, both layers can be extruded simultaneously from the same sheet die, which is known per se and therefore is not described in more detail. Behind the sheet die 1, there are two rollers 4,5 which are pressed against one another. The roller 4, which is described as the pressing-on roller in the following, has a sleeve 4a made from rubber elastic material. The other roller 5, which is described as the laminator roller in the following, is cooled with cooled water, which flows through the interior of the laminator roller 5. The metal strip M with the still liquid plastic film 3 is fed through a gap 6 between the two rollers 4,5 and thereby

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pressed by the laminator roller 5 onto the metal strip M. The liquid plastic film 3 should be pressed onto the metal strip M with a force of at least 60 N/mm applied to the width of the steel strip. The cooling rate of the laminator roller 5 should be set in such a way that a cooling rate of at most 400W/m²_C results. While the plastic film 3 is adjacent to the laminator roller 5, its surface layer at least must be converted by cooling into a firm condition, before the surface of the laminator roller 5 is separated from the plastic film. For that reason, a second cooling laminator roller 7 and a second pressing-on roller 8 are arranged in such a way that the metal strip M is looped round the preceding first laminator roller 5 on a part of its circumference and the metal strip with the still liquid plastic film adjacent to the laminator roller 5 is held in contact at the first gap 6 over a part of the circumference of the roller 5 in an arrangement with the latter. In front of the second laminator roller 7, a second sheet die 9 is arranged, with which a second liquid plastic film 10 can be extruded on the second side of the metal strip. Said second liquid plastic film is then pressed by means of the cooling laminator roller 7 onto the second side of the metal strip in the previously mentioned manner. The sheet die 9, the laminator roller 7 and the pressing-on roller 8 together form the second lamination station. In the direction of the belt behind the second laminator roller 7 a deflection roller 19, which may likewise be designed as a cooling roller, is once again arranged such that the metal strip M loops round the second preceding laminator roll 7 on a part of

its circumference and the metal strip with the still liquid plastic film 10 which is adjacent to the laminator roller 7 is held in contact at the second gap 11 over a part of the circumference of the second laminator roller in an arrangement with the latter, till at least the surface of the second film 10, which is adjacent to the laminator roller 7 was cooled down into a firm condition. The length of the encircling of each laminator roller 5,7 or the length of contact depends upon the speed of the belt, the thickness and type of metal strip, the thickness of the plastic films and the temperature of the laminator rollers. Experiments with a steel strip of 0.26 mm thickness and a PP plastic film of 200μm thickness gave the result that, with a laminator roller temperature of 40°C, the contact time on the laminator roller must be 60 ms and the contact length, with which the plastic film must be kept in position on the contact roller, must be 200 mm at a belt speed of 200 m/min. If the temperature of the laminator roller is at 60°C, then the contact time must be 80 ms and the corresponding contact length 270 mm.

In order to make sure of a flexible gap compensation in the gap 11, in case variations in film thickness occur the pressing-on roller 8 can usefully have a sleeve 8a, which is made of rubber elastic material and which is surrounded concentrically by a thin, outer steel sleeve 8b which is flexible in a radial direction. Using a steel sleeve 8b, prevents the pressing-on roller 8 from leaving behind unwanted patterns on the first plastic film 3, which may

occur if the sleeve made of rubber elastic material were to sit directly on the plastic film.

For reasons which have already been described in greater detail in the description of the method, the width of the sheet die 2 is greater than the width of the metal strip M. This leads to the fact that the plastic film 3 juts out on each side of the metal strip M by 20 mm to 30 mm. The liquid plastic film would adhere to the pressing-on roller 4. In order to prevent this, continuous Teflon strips are provided on both sides of the steel strip M, said strips being directed via the pressing-on roller 4 and two deflection rollers 13,14. The deflection roller 14 is thereby likewise arranged such that the protruding plastic film is pressed onto the laminator roller 5 until it is converted into a solid condition by cooling. The protruding plastic film is therefore only separated from the Teflon strips 12 after cooling and setting of the plastic material also. The protruding part of the plastic films is later cut off using trimming rollers 15, which are arranged on both sides to the laminated metal strip, and sent for recycling.

In the description of the method, it was explained extensively, that subsequent treatment of the laminated metal strip by heating and then fast cooling down in a water bath are mandatory. This is achieved by means of the heating device 16, which is only represented in Figure 1, and the connected cooling device 17 which consists of a water bath.

The embodiment example which is represented in Figure 2 corresponds essentially to the previously described embodiment example. Devices and parts with the same function are thus designated with the same reference numbers. So that repetitions are avoided, reference is made to the embodiments shown in Figure 1.

In the embodiment example represented in Figure 2, the second laminator roller 17 is arranged such that it faces the first laminator roller 5 and can be pressed onto the latter. In order to ensure a certain flexibility here in the gap 11 as well, the second laminator roller 7 can have a sleeve 7a made from rubber elastic material, and be surrounded concentrically by a thin outer steel sleeve 7b which is flexible in a radial direction. In this arrangement, the second pressing-on roller drops out of use, since the first laminator roller takes over the function of the second roller 7.

In the solution which is represented in Figure 3, a first sheet die 21 is arranged on the first side of the metal strip M and a second sheet die 22 on the opposite side of the same. Underneath both sheet dies 21,22 a first laminator roller 24 and a second laminator roller 25 are situated beside one another and can be cooled appropriately by means of water so that they can be set at a temperature of 20-80°C. A deflection roller 23, which is connected to the first laminator roller 24, makes certain

that the metal strip, which surrounds the laminator roller 1 by around 180° in this case, is in contact with the gap 26 which is formed between the two laminator rollers 24,25 which are pressed against one another. It is ensured in this way, that the film is pressed onto the metal strip M by means of the first sheet die 21 firstly in the gap 26 through the laminator rollers 24 and 25 which face one another and then the metal strip with the first plastic film 27 which is at first still liquid is held in contact with the gap 26 in an arrangement with the first laminator roller 24 until the first plastic film 27 is cooled down by the laminator roller 24 and converted into a solid condition. Only then does the first plastic film 27, which is adhering securely to the metal strip M, separate from the surface of the laminator roller 24.

A continuous laminator belt 28, which consists appropriately of steel, is directed over the second laminator roller 25, which appropriately has a rubber elastic sleeve 25a. Furthermore, two deflection rollers 29, 30 are provided for directing the laminator belt 28, said rollers being designed appropriately as cooling rollers. The deflection roller 29 is arranged such that the laminator belt surrounds the first laminator roller 24 in that region, in which the laminator roller 24 is also surrounded by the metal strip M. In this way, the second plastic film 31 which has been extruded by the second sheet die 22 can be pressed onto the metal strip by the second laminator roller 25 by inserting the laminator belt

in the gap 26. The second plastic film 31 is then, in contact with the gap 26, pressed onto the metal strip M, furthermore, during the partial surrounding of the first laminator roller 24 until the second plastic film is cooled down into a solid condition. Cooling is achieved thereby using the laminator belt 28, which has been cooled down by the cooling rollers 29,30 and the second laminator roller 25. Additional cooling is achieved using the first laminator roller 24. This modus operandi is adopted when similar plastic materials, with similar melting points are to be deposited on both sides of the metal strip e.g. PET on both sides or PP on both sides.

As can be seen from Figure 3, a pressing-on roller 32 is also assigned to the first laminator roller 24, said pressing-on roller having a sleeve 32a of rubber elastic material appropriately. The laminator roller 32 is arranged in the direction of the circumference of the first laminator roller at a greater spacing from the gap 26, which is formed between the two laminator rollers 24,25. The first sheet die 21 can be adjusted from its first pouring position, which is fully opened-out in Figure 3, into a second pouring position which is shown in Figure 3 with dotted lines. If plastic materials with different melting points are to be deposited on both sides of the metal strip M e.g. on the first side PET and PP on the second side, the first sheet die is then brought into its second pouring position, which is shown with dotted lines. The steel strip is then directed round the pressing-on roller 32 and through the gap 33 which is

formed between the pressing-on roller 32 and the first laminator roller 24, as is shown likewise with dotted lines in Figure 3. By means of the first die 21, the plastic material with the higher melting point, e.g PET (melting point 280°C) is extruded on the steel strip M in the region of the pressing-on roller 32. In the gap 33, the still liquid plastic film 27a is pressed through the laminator roller 24 onto the first side of the metal strip. Similarly, as in the embodiments which are described and represented in Figures 1 and 2, the first plastic film 27a is still held after the gap by the metal strip in an arrangement with the laminator roller 24 and cooled down. At the same time, the metal strip is also cooled down. The spacing between the pressing-on roller 32 and the gap 26 is decided upon in such a way that the metal strip in the gap 26 always has a temperature above the melting point of the second plastic film, e.g. PP (melting point 140 -160°C). By means of the second sheet die 22, the second side of the metal strip M can be laminated with the second liquid plastic film 31, consisting of PP, in the manner already described.

In order to avoid contamination of the pressing-on roller 32, continuous Teflon strips 12 are also provided here in the region of the pressing-on roller 32, said Teflon strips 12 corresponding in design and function to those shown in Figure 1. The description given for this purpose in connection with Figure 1 can be applied logically also to Figure 3. The same is also true with respect to the

device for subsequent heating and the cooling device which are not shown in Figure 3.